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AND ABSTRACT OF THE LITERATURE

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A Work Chair

Practical Hygienic Efficiency of the Palmer Apparatus for Determining Dust in Air

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VOLUME III SEPTEMBER, 1921 NUMBER 5

FATIGUE AND ERROR IN A MENTAL OCCUPATION *

J. P. BAUMBERGER

(From the Laboratory of Physiology, Stanford University)

RECENTLY some doubt has been thrown upon the use of output studies as a criterion of fatigue in industrial occupations (1). The data reported in this paper, however, show that the number of errors as well as the output varies during the day in a manner typical of fatigue curves. Link (2) in his investigations has used psychological tests as a method of studying fatigue, but although the tests were given at various times during the day, they showed very little indication of fatigue. In this paper output rate and error in a normally recurring routine operation of short duration are used as a measure of fatigue.

PROCESS

Permission to work in the auditing department of a large railroad company was obtained through the courtesy of the superintendent, and the records of eighteen women clerks were compiled. The processes studied were the writing in of names on pay checks with pen and ink, and the typing in of amounts using a machine, in each case the name or amount being obtained from the payroll. Six women were engaged in writing in amounts, and twelve in writing in names. Three of the clerks worked on both processes.

It is the rule in this company that all pay checks must be numbered consecutively, and that the numbers of all checks on which mistakes are made must be recorded. Furthermore, the following data are kept in tabular form by the head clerk: time consumed in writing and comparing payroll vouchers — name of clerk, commencing number, closing number, number of names of payees written in with pen (or amounts typed in by machine)—time commenced, time finished, minutes, number of checks canceled.

TREATMENT OF DATA

From the mass of data on the time consumed in writing and comparing payroll vouchers, I copied all the records for each of eighteen women clerks for the month of September, 1919. The total number of checks involved was 114,314. During this month the clerks had worked on pay checks on about fifteen to twenty days, but only for a few hours on each of these days, as a transcription from our data clearly shows. (Table 1.) The remainder of the time was

* The author wishes to acknowledge his indebtedness to Dr. E. G. Martin for advice and to Miss Edna Perry for assistance in connection with this paper. Received for publication April 26, 1921.

spent in the routine work of the auditing department.

The data were treated as follows: All the output records for one individual for one process were grouped together by hours. When a period extended into two hours the record was assigned to the hour nearest the center of the period — *e. g.*, 1.40–2.35 was put in the 2–3 hour, and 11.55–1.00 in the 12–1 hour. The output rate per hour was then calculated for each hour of the day and compared with the grand arithmetical mean of all the hourly records of the clerk. Calling the latter figure 100, by a simple proportion the figures of the individual hours were reduced to percentages of the grand average. This statistical treatment was gone through for each clerk and each process. The advantage of the data thus obtained is its freedom from differences due to skill and to the different speeds of the two processes of writing names and amounts. The percentage output for each hour for the whole group was found by obtaining the true mean of a frequency curve in which the percentage outputs for the hour for each individual were the quantities, and the number of checks on which each quantity had been based were the frequencies. This method was followed on the assumption that the percentage outputs having the largest number of checks as a basis were the most reliable.

TABLE 1. — SAMPLE OF DATA SHOWING TIME CONSUMED IN WRITING AND COMPARING PAYROLL VOUCHERS

Name	Date	Number of Names by Pen	Number of Amounts by Machine	Number of Checks Canceled	Time Commenced	Time Finished	Minutes
H.....	9/5/19	....	143	7	1:00	1:35	35
		125	....	1	11:10	11:40	30
		....	125	0	(12)11:55	1:00	25
		....	151	6	3:00	3:50	50
		156	....	3	(2) 1:40	2:35	55
		....	156	4	2:35	3:00	25
		....	172	6	(4) 3:50	4:30	40

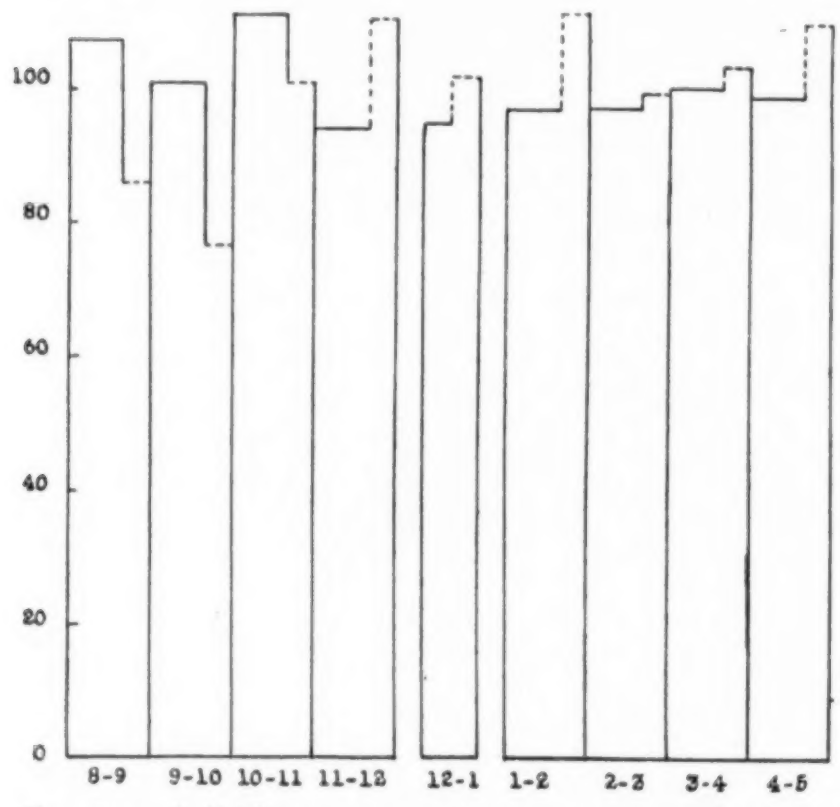

FIG. 1. — Solid line = percentage output rate by hours. Broken line = percentage error output rate by hours.

Checks were canceled when errors were made; therefore a record of the canceled checks for each hour and each individual gives the number of errors made. The percentage of error for each individual for each process and each hour was calculated and compared with the day's average errors as 100, and these figures were considered as quantities in a frequency distribution with the number of checks as frequencies, and the true mean obtained for each hour.

OUTPUT AND ERROR

The percentage output rate by hours is shown in Table 2 and Figure 1. It will be seen that the output rate starts at 106.8, falls to 100.5 in the second hour, goes up to 111.1 in the third, and falls at noon to 94.2. Lunch is had between 12 and 1 with forty

minutes allowed, therefore the output rate of 94.8 for this hour may not be significant. The output rate at 1 P.M. is 96.7 and increases to 100 by 3 o'clock, falling only slightly (to 98.8) at the end of the day. The output curve is, therefore, not very typical of fatigue; it shows, however, the characteristic higher output of morning (103.1) over afternoon (97.5).

The percentage output rate of errors by hours is also shown in Table 2 and in Figure 1. The percentage rate of errors starts at 86.1 falls to 76.6, then goes up to 110.3 at noon. At 1 o'clock it starts at 111.8 (the highest for the day), falls in the second hour to 99.9, then goes up to 109.4 at the end of the day. The morning average is 93.6, and the afternoon average 105.3 Not considering the 12–1 hour, the curve of percentage error output is the converse of a typical output curve. This is shown if we plot the reciprocals of the percentage error output, *i. e.*,

$$\frac{1}{\text{percentage error output}},$$

which we will call quality of work. This

TABLE 2. — HOURLY OUTPUT RATE AND RATE OF ERRORS

Time	8–9	9–10	10–11	11–12	12–1	1–2	2–3	3–4	4–5
Hour	1	2	3	4	5	6	7	8	9
Output									
Mean	106.8	100.5	111.1	94.2	94.8	96.7	97.3	100.0	98.8
Standard deviation	22.1	11.8	8.2	7.3	7.6	4.9	15.8	16.5	10.5
Probable error of mean	0.4	0.2	0.12	0.12	0.06	0.04	0.34	0.19	0.12
Difference	6.3	10.6	16.9	0.6	1.9	0.6	2.7	1.2	
Probable error of difference	0.44	0.42	0.17	0.22	0.23	0.35	0.35	0.5	
Number of times P. E. D. is contained in difference	14.3	25.7	99.4	2.7	8.3	1.7	7.7	2.4	
	A.M. Average 103.1				*P.M. Average 97.5*				
Error									
Mean	86.1	76.6	101.6	110.3	101.9	111.8	99.9	103.7	109.4
Standard deviation	34.2	20.0	26.4	28.4	34.1	33.8	25.6	28.9	37.3
Probable error of mean	0.21	0.1	0.12	0.14	0.25	0.27	0.18	0.21	0.42
Difference	9.5	25.0	8.7	8.4	9.9	11.9	3.8	5.7	
Probable error of difference	0.23	0.15	0.18	0.28	0.37	0.32	0.28	0.47	
Number of times P. E. D. is contained in difference	41.3	167.0	48.3	30.0	26.8	37.2	13.6	12.1	
	A.M. Average 93.6				*P.M. Average 105.3*				
Quality of Work	116.0	131.0	98.5	88.4	98.2	84.8	99.9	96.5	91.3
	A.M. Average 108.5				*P.M. Average 94.1*				
Efficiency	124.0	131.0	109.5	85.3	93.0	86.5	97.3	103.7	90.3
	A.M. Average 112.4				*P.M. Average 94.2*				

is shown in Table 2 and in Figure 2. The quality is good to start (116), better in the second hour (131), but then falls off to 88.4 at noon. It starts low in the afternoon (84.8), climbs to 99.9 in the second hour, and falls off to 91.3 at the end of the day. The morning quality average is 108.5 as compared with 94.1 for the afternoon.

The efficiency of the workers for each hour is determined by their output and the

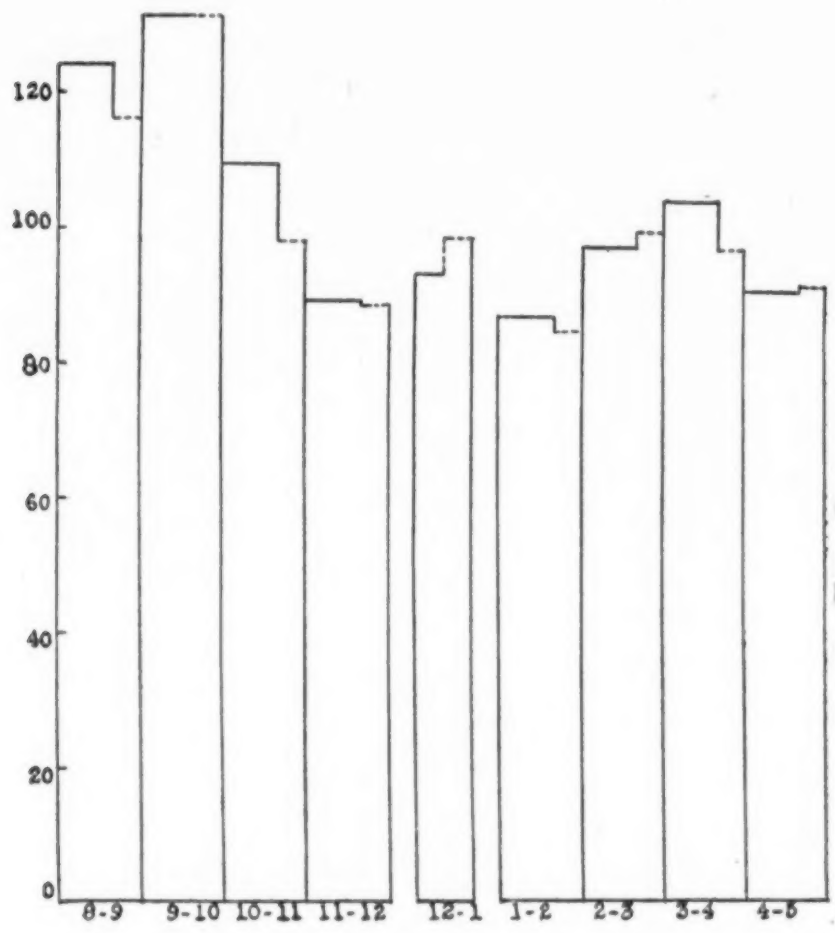

FIG. 2. — Solid line = efficiency by hours. Broken line = quality of work by hours.

quality of the work and may be obtained by dividing the percentage output rate by the percentage error output, for each hour. This is called the efficiency curve and is shown in Figure 2 and in Table 2. The efficiency starts high at 124 and climbs in the second hour to 131, then falls by noon to 85.3. At 1 P.M. it starts at 86.5, climbs to 103.7 in the third hour, and falls to 90.3 by the end of the day. The morning average is 112.4 and the afternoon 94.2. This curve has also most of the characteristics of a fatigue curve.

DISCUSSION

The data in Table 2 show that production is maintained more evenly throughout the day than quality. Thus, the difference between the highest and lowest percentage output hours is only 16.9, as compared with 35.2 for percentage error output. It is probable that the writing or typing is an automatic movement (3) in which the individual is unconscious of the figures read but conscious of the (voluntary) movements required to write the name or the number. In order to be aware of errors made, a higher form of consciousness — attention — is required. It would seem that the output is maintained by the lower type of consciousness, but the quality varies with the higher type of attention which is more readily subject to fatigue. Attention is more easily diverted than unconscious volition, and this may explain why the percentage output of error is more variable then the percentage output.

In this connection Spaeth (1, p. 32) says:

> . . . The question now arises as to what light the output curve throws on the occurrence of fatigue. We may say at once that if by fatigue we mean a lowered capacity for work, and the drop in output indicates a lowered capacity for work, it must simultaneously indicate, by definition, the presence of fatigue. How much of this fatigue is due to the work and how much to other conditions, output curves do not tell.

From the data above it would seem that even though the percentage output of the individual does not follow a fatigue curve very closely, the quality of the work does so to a very decided degree. It appears, therefore, that the decline in output at the end of the morning and the lower output of the afternoon are really indicative of fatigue — that is, if it is admitted that lessened attention is due to fatigue. The fact that production is maintained at so near a level throughout the day would indicate that the workers are endeavoring to keep up their output; in spite of this, however, the errors increase. It would seem, therefore, that real fatigue is the cause of the lowered output.

Link (2) made a study of the quality of the work done in a munition factory and concluded that "there was not enough difference in the quality of the work done at various times of the day to justify reducing the number of hours." He gives the following table (Table 3) showing the percentage of scrap that had escaped rejection by inspectors at various times of the day. The figures in parentheses in the table are mine and show the percentage of each

> tests are entirely too short for reliability, even if carried on five times a day for a period of three weeks. Moreover, as has since been discovered in connection with the development of psychological tests for aviators, the human mind is able to concentrate for short periods even when it is almost on the point of exhaustion and render for such a time a performance which compares favorably with those done under the most favorable conditions.

From Figure 1 on page 235 of Link's paper, however, it appears that the number of errors in the 5.40 P.M. test was about 25

TABLE 3. — PERCENTAGE OF SCRAP FOUND BY REINSPECTION (*AFTER LINK* (2))

Time of Original Inspection	7–8 A.M.	1–2:30 P.M.	5–6 P.M.
Number of boxes inspected	47.0	26.0	37.0
Percentage of total scrap found by reinspection	12.2 (101.0)	8.5 (70.0)	15.5 (129.0)
Percentage of scrap (based on total number of shells inspected) found by reinspection	3.9 (99.0)	2.6 (66.0)	5.3 (135.0)

figure of the average for the whole day as determined from the three figures given in the table. The percentage comparison (in parentheses) shows that the inspection work in the 5–6 hour is about 30 per cent. inferior to that of the morning hour. Therefore, Link's conclusion that "this increase is comparatively slight" (page 234) seems unwarranted.

Link gave a number of psychological tests at different periods during the day from which he concludes (p. 237):

> The results in the tests, in so far as they were indicative, coincided largely with the results of the reinspection and production study. However, the variations in the quantity and quality of the work done in these tests were altogether too slight to justify using them as an index of fatigue. On the other hand, the variations due to practice were so marked as to make all other variations seem insignificant. This is not necessarily a repudiation of the psychological method, but rather an indication of the difficulties involved. It would seem that two-minute

per cent. more than in the 1.10 P.M. test. As Link points out, a psychological test arouses the individual to unusual concentration of attention which may mask the effects of fatigue. Our use of a normally recurring routine occupation of a duration of only a few minutes as a measure of fatigue is therefore valuable in that it escapes the danger of arousing unusual attention by its nature.

Conclusion

1. Output in clerical work shows signs of fatigue.
2. The error output in clerical work is the converse of an output curve.
3. The efficiency of clerical workers as measured by output and errors made varies like a typical fatigue curve.
4. A normally recurring routine occupation of a few minutes' duration is a valuable criterion of fatigue.

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A WORK CHAIR *

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SURVEYS of twenty stores have disclosed a number of hygienic faults, one of the most evident of which is unnatural seating. Unnatural posture causes fatigue, reduces vitality, tends to deformity, and always results in reduced production and earning power. A careful search of chair salesrooms has disclosed the fact that no suitable chair is in stock which can be said to meet the anatomical and practical needs of the employee whose work is done at a desk or table.

In the past, chairs were evidently designed for resting, not for working. The common bent wood chair shown in Figure 1 supports only the shoulders when one leans back, and is an instance in point. The cane seat of this chair weakens rapidly so that the worker is soon sitting on a wooden ring crossing under the middle of the thighs.

A casual glance at any group of clerical employees at work will show a large proportion of them sitting forward on the front part of their chairs, as illustrated in Figure 2. This is an attempt to get comfortable. The back of the chair is used only during intervals of rest from fatigue produced by sitting with no support to the back. (See Figures 1 and 3.) Where does one need support when sitting at desk work? Try this experiment and see for yourself. Sit erect, and then gradually relax, letting the back bend naturally. You will find at once that the small of the back bulges directly backward. Here, then, is the need for support to maintain the erect position — the natural position for work. The weight of the body should be supported by a seat directly under the body and not at the mid-thigh. To meet these requirements of nature the chair shown in Figure 4 was made. It possesses a shallow seat and a back curved forward to fit the small of the back, and is of rigid construction in order to give support and steadiness. This chair has proved to be a generally useful work chair and considerable search has failed to discover any other which approaches it in essential requirements. Adjustable chairs may still be necessary for special work, such as that of the telephone switchboard operator, but adjustability is not an unmixed good. It nearly always results in unsteadiness and the chair is rarely correctly adjusted to the individual. Moreover, adjustability requires frequent repairs and results in a short-lived chair.

To introduce successfully any radical change in an individual's working environment — and a new work chair constitutes such a change — requires tact and care. It is suggested that at first a few samples be introduced, with careful explanations as to the object of the chair and with the suggestion that a fair trial be made before judgment is passed.

The work chair, which we have described, was especially designed by a committee composed of Dr. Joel E. Goldthwait (chairman), Dr. Lloyd T. Brown, and Mr. Ford, of Massachusetts Institute of Technology, to meet the needs of a large technical educational institution. It has proved entirely satisfactory, when used at a table or desk. Another similar chair, with arm rest added, was constructed for ordinary

* Received for publication May 31, 1921.

FIG. 1. — Resting posture in common bent wood chair.

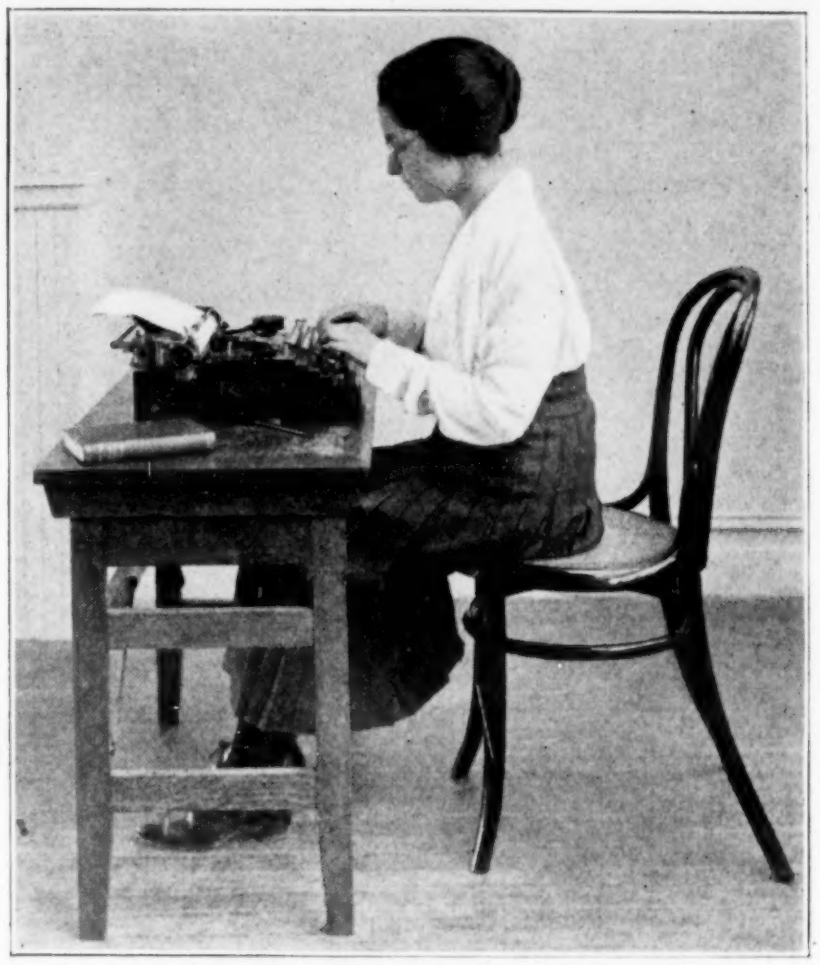

FIG. 2. — Correct working posture in common bent wood chair.

FIG. 3. — Posture when sitting back in common bent wood chair.

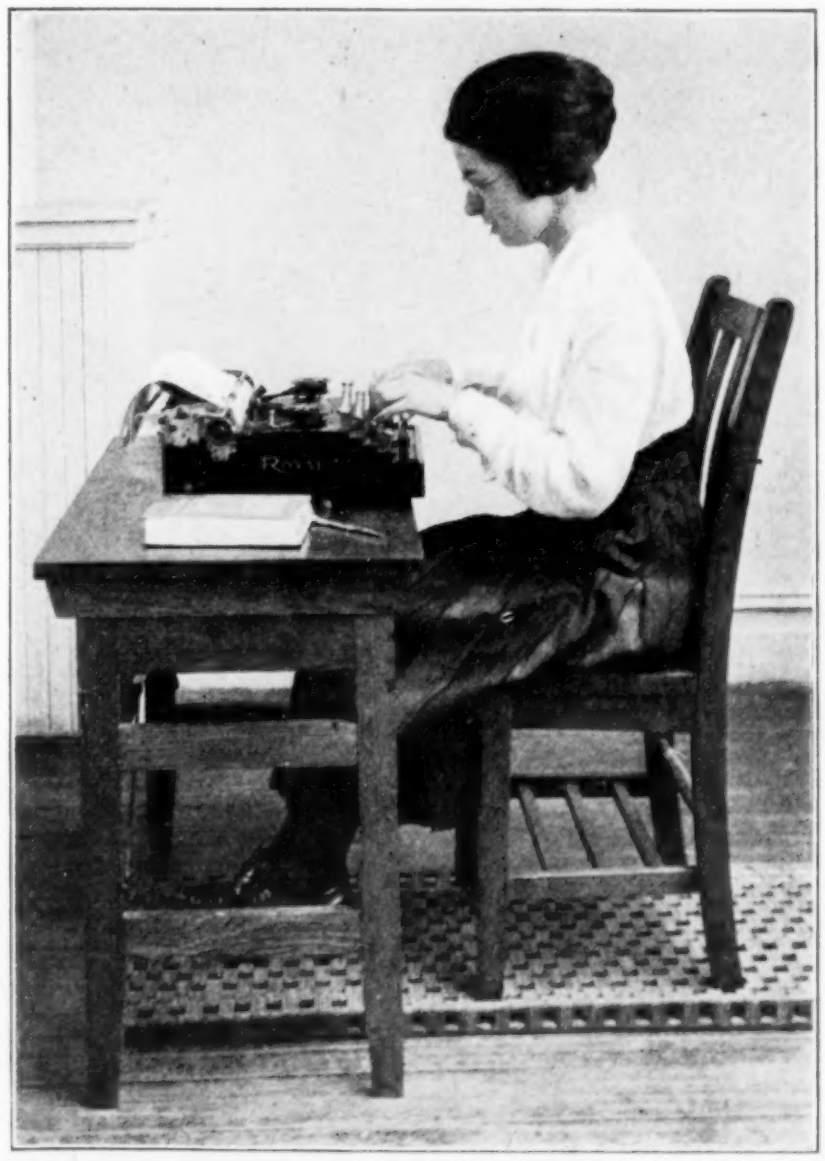

FIG. 4. — Correct working posture in work chair.

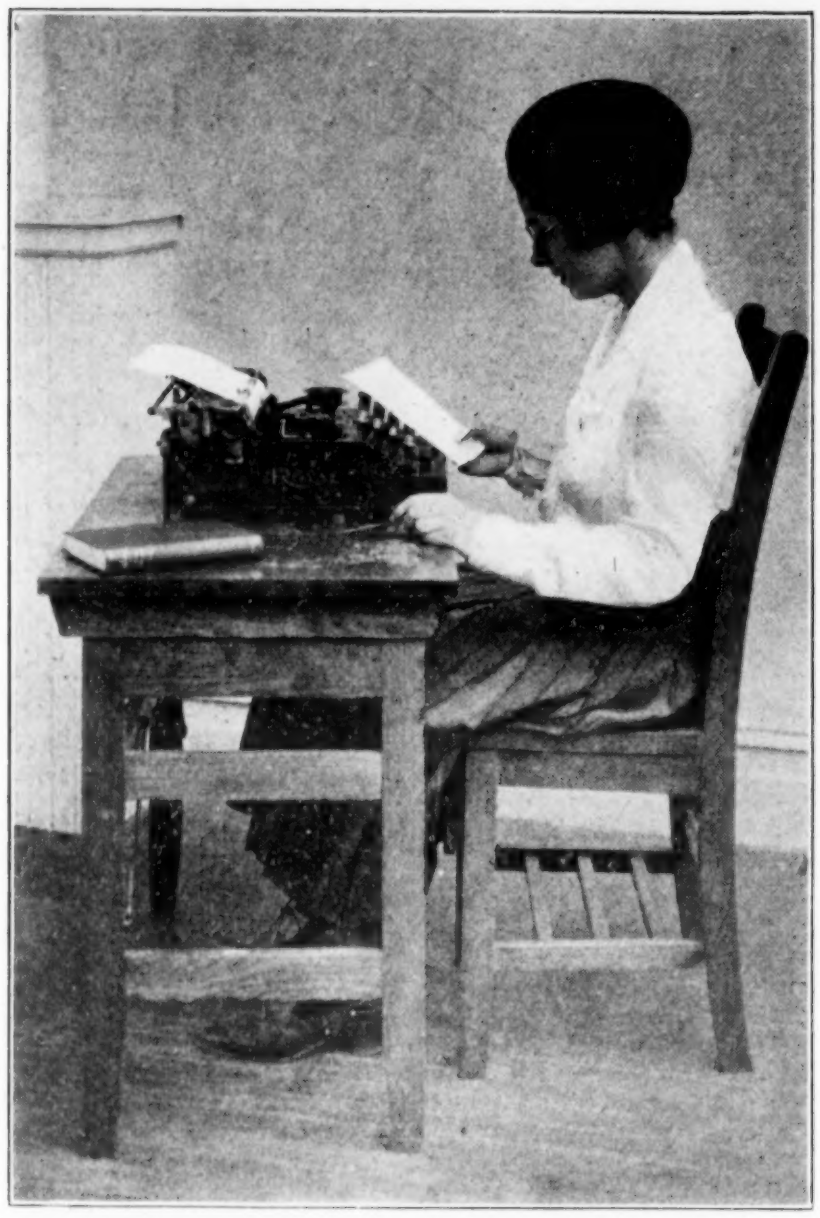

FIG. 5. — Correct resting posture in work chair.

FIG. 6. — Work chair.

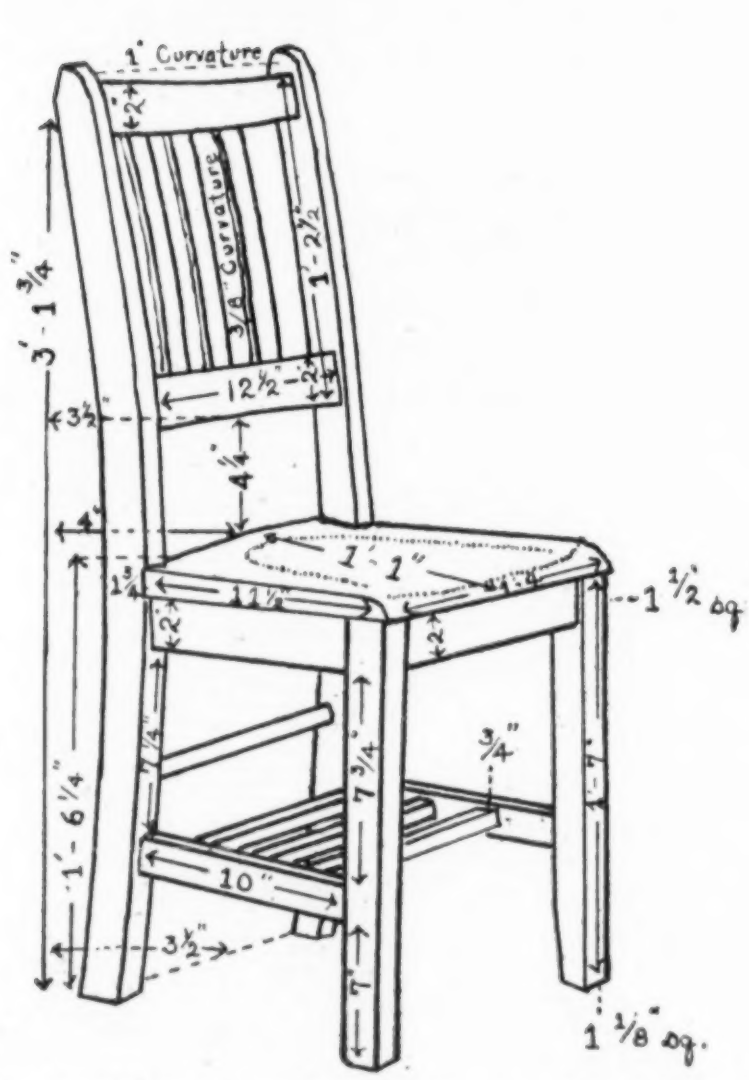

FIG. 7. — Manufacturer's measurements for work chair.

class room or lecture work. The sturdy construction of the chair is testified to by the fact that several hundred have been in constant use for five years and are reported to have received no repairs. Inspection of them at the present time shows that the glue has given way and needs replacement in about one in five to ten chairs; otherwise the chairs are in good condition.

The chair has had industrial use in a large clothing factory where many machines are used at tables. The personnel director of this establishment reports as follows:

> We have found that the four different heights of the chair (17″, 18″, 19″, 20″) we use have been sufficient for all but one or two exceptional cases. The

FIG. 8. — Correct working posture in work chair.

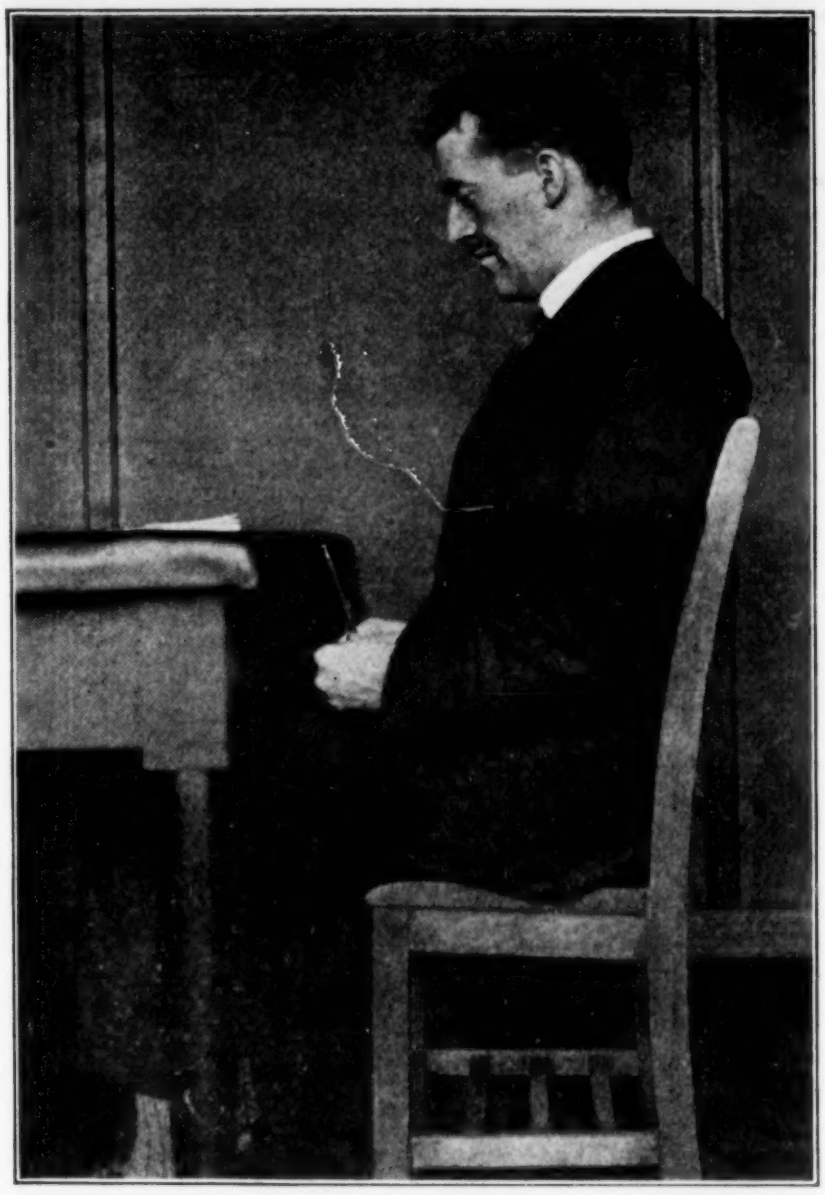

FIG. 9. — Correct resting posture in work chair.

FIG. 10. — Incorrect working posture in common office chair.

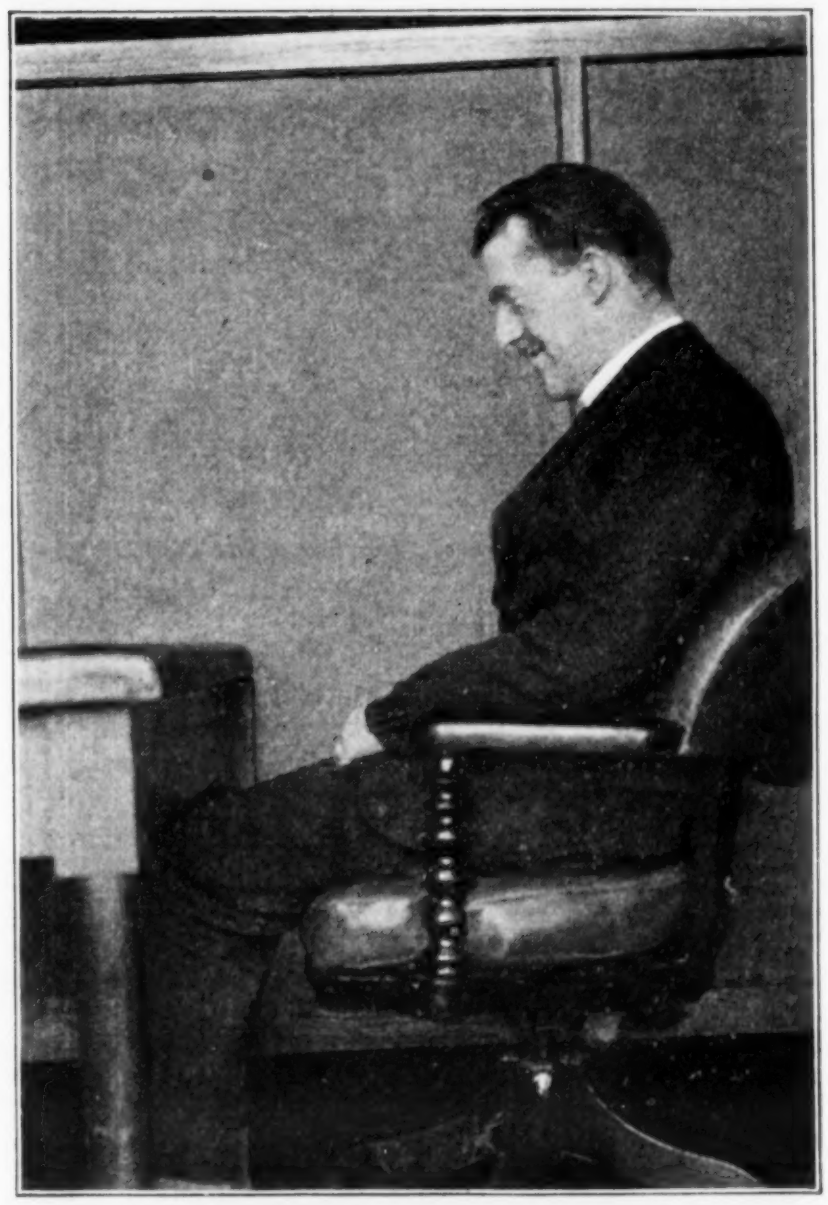

FIG. 11. — Resting posture in office chair.

chair has worn very well indeed and is giving great satisfaction to the workers. As for its preventing fatigue, I cannot furnish statistics on this matter, but I do know that any chair which supports the back as this one does and which does not interfere with circulation must have a great deal to do with reducing the fatigue of our workers. I have used this chair myself ever since we first introduced it in the factory, and I wouldn't use any other as a desk chair. I feel that it has helped me to maintain correct posture, and that I am very much more comfortable in it than in any chair I have used as a work chair.

When we take into consideration the fact that many workers in stores, offices, and factories spend nearly a third of the twenty-four hours of a day in a chair, the importance of correct posture in preventing fatigue during working hours is evident. It is hoped that employees whose work must be done at a table or desk may be given the opportunity to use the work chair described in this article and to enjoy the comfort which it insures.

THE PRACTICAL HYGIENIC EFFICIENCY OF THE PALMER APPARATUS FOR DETERMINING DUST IN AIR*

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IN view of the recent publication of two rather severe criticisms of the efficiency of the Palmer water spray method of dust sampling, it has seemed to us that it would be advantageous to publish the results of some actual studies of dusty air made with the Palmer apparatus as compared with studies of sections from lungs of animals exposed to the same dusty air and with counts made directly from samples of the dust used in the tests. The criticisms referred to were those of Bill in his paper on *The Electrostatic Method of Dust Collection* (1) and of Katz *et al.* on the *Efficiency of the Palmer Apparatus for Determining Dust in Air* (2). Bill claims a relative efficiency of 61.6 per cent. by weight and 59.9 per cent. by count of the Palmer apparatus as compared with the electrostatic method, which later method he found to retain 82.3 per cent. by weight of the dust passing through his apparatus. Katz and his co-workers claim only a 70 per cent. efficiency for the electrostatic method and an efficiency of 30 per cent. or less for the Palmer apparatus.

It seems to us that the tests used by Katz and his co-workers were entirely too severe and not at all comparable to industrial conditions under which either apparatus is likely to be used. They start with the premise that the finest air-suspended particles are the most injurious to the lungs — a fact that has never been proved and that seems to us to be doubtful. Hoffman in a recent article (3) also conveys this idea when he speaks of "extremely fine dust, the ultramicroscopical particles of which are most harmful to the lungs." With all macroscopic foreign bodies, other things being equal, the larger the body the greater the irritation produced, and, of course, with soluble toxic particles the larger the particle the more toxic it is. It would seem to us that the largest particles that would actually reach the lung tissue would be most harmful and the particles that were most numerous in the lungs would be those most apt to produce gross lesions. Katz employed two methods of testing the apparatus, one with filtered tobacco smoke containing particles (droplets) of uniform size ranging from 0.2681 to 0.2779 microns in diameter. Efficiency was tested by the Tyndall phenomenon of luminosity of the particles floating in a current of air traversing a beam of light. Air passed through the Palmer apparatus was compared with air by-passed around the apparatus, percentage of suspended matter removal being calculated from the amount of filtered dust-free air required to dilute the latter sample so as to make the two beams of light of equal luminosity. This is a very ingenious method and the complicated apparatus required to make the test is most interesting, but the long, narrow, more or less tortuous tubing through which the samples are passed offers, as the authors state, abundant opportunity for precipitation of particles on the sides of the tubes. The test showed about 13 per cent. removal of these very minute droplets of liquid. Similar tests with finely divided dried silica dust showed a removal efficiency of 30 per cent. by the Tyndall method.

The second method employed by Katz was to collect the silica dust passing the Palmer apparatus in a small Cottrell elec-

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trostatic precipitator. The dust collected by the Cottrell precipitator was filtered through an analytic filter and weighed on the filter, the dust in the filtrate being estimated by a turbidity reading of the filtrate as compared with the turbidity of suspensions of known weights of the finest air-floated silica dust. This does not seem as accurate a method as that used by Bill and by Miller and Smyth (4) for determining the weight of dust collected by the Palmer apparatus. Just why the suspended water sample was not evaporated and the residue weighed, does not seem clear from the article. No direct measurements are given of the size of the silica particles used, but it is stated that those that pass through the analytical filter-paper average 0.25 microns in diameter. This method showed an efficiency of 45 per cent. by weight with this very fine dust. These tests show undoubtedly that the Palmer apparatus allows many minute particles to pass through, but they throw no light on the efficiency of the apparatus for sampling the average industrial dust clouds that contain many particles of much larger size which, as will be shown later, are still within the range of those that reach the lungs and remain lodged in the tissues.

In Katz's experiments, air was passed through the Palmer bubbler at the rate of 4 cubic feet per minute. Tests at a slower rate showed less efficiency, and tests at 5 cubic feet per minute, as recommended by Palmer, carried water through the apparatus. Bill, in his tests, used the same rate for the same reason. The work reported by Miller and Smyth (4) was mostly done at the 5 cubic foot per minute rate, the apparatus used being mounted in a dress suit case as originally designed and described by Palmer (5). The collecting bulb in this apparatus is larger than that in the later designs and has an extra bend in the outlet tube, and this is connected with several inches of upright and horizontal tubing before the fan is reached. With this original apparatus we have never known water to be carried over to the fan at the 5 cubic foot rate, and we always use this rate of sampling provided we have sufficient current for the fan motor. Many industrial plants manufacturing their own current use a 210 to 220-volt current, and by the introduction of a 110-volt lamp in parallel circuit and a four-point switch we have been able to use the same apparatus for tests in these plants and in plants using the usual 110-volt current.

Bill compared the Palmer apparatus with an apparatus of his own design, using a small Cottrell precipitator and running both types of apparatus for sixty minutes, which seems a much better sampling time than the one-minute periods of Katz. Bill used dusts passing a 100-mesh sieve which would much more nearly approach the average industrial dust than does tobacco smoke or the cotton-filtered silica dust of Katz, and would include, as will be shown later, the largest particles ever found in lung tissue. Bill found an actual efficiency of his own apparatus of 82.3 per cent. by weight and a comparative efficiency of the Palmer apparatus, as compared with his own, of 59.9 per cent. by count and 61.6 by weight, making an absolute efficiency by weight of 50.69 per cent. Bill claims that in counting particles in Palmer samples he was much more troubled by the clumping of smaller particles into masses which he often counted as units than he was with water suspensions of electrically precipitated dusts. Miller and Smyth and later we ourselves found that sufficiently vigorous shaking of samples and sufficiently high dilutions with filtered distilled water resulted in breaking up practically all of these clumps. In our counting work we dilute very turbid samples from 1 in 10 to 1 in 100, so as to have counts of under 100 particles per one-fourth field. This probably materially increases total counts and espe-

cially counts of smaller particles, and shows a greater percentage efficiency by count than was found by Bill, though even the approximate 50 per cent. efficiency of the Palmer apparatus as demonstrated by Bill does not materially affect its usefulness provided this percentage efficiency is reasonably constant and provided the apparatus gives a representative sample of particles of the most effective size. Bill's apparatus, while undoubtedly giving a decidedly greater percentage efficiency by count and by weight than does the Palmer apparatus, requires more delicate and skilful manipulation and more technical knowledge in order to run it and is as yet far from a portable and practical apparatus for routine industrial dust sampling. It is greatly to be hoped, however, as Bill himself suggests, that these latter difficulties may be overcome and that there may soon be designed and put on the market a small portable apparatus which can be used with reasonable facility and accuracy by the average field worker.

Experimental Work

For over a year we have been doing experimental work along the lines followed by Mavrogordato (6), exposing groups of guinea-pigs to measured clouds of fine dust for given periods at given intervals. After given periods of time, the animals were killed and the effects of dust inhalations on the lungs were studied, the method of entry of dust to the lung tissue, the location of permanent deposits, the rate of invasion, and the route and rate of elimination of dust particles from the lungs all being noted. It is not the purpose of this paper to report on this work other than in one particular — that of the size of particles lodging in lung tissue. For this work a dust box was constructed similar to that described by Mavrogordato, a small electric fan being used to keep dust in suspension. A hole was so placed in the box that samples could be taken by the Palmer apparatus from alongside the exposed animals. Counts were made according to the method suggested by one of us (7), particles much over 40 microns in diameter being ignored and those counted being divided into three groups based on their greatest diameter rather than on their estimated area. The particles in group I averaged 40 microns, being sufficiently large so that their area could be easily estimated. Group II particles averaged from 5 to 30 microns in diameter and were large enough for their shape to be determined but many were too small for their area to be estimated. Group III particles averaged 1 micron and appeared under the low power as dots too small to permit us to determine their form.

Table 1 gives the size distribution of particles in watery suspensions of samples

TABLE 1. — SIZE DISTRIBUTION OF PARTICLES IN DUSTS USED IN TESTS

Kind of Dust	Size I Av. 40 Microns Diameter	Size II 5–30 Microns Diameter	Size III Av. 1 Micron Diameter	Number of Particles Counted	Relative Weight of Equal Bulk of Dust
	%	%	%		
Coal.....	2.9 +	16 +	81 +	549	1.0
Stone....	0.78	9 +	90 +	2,529	1.8
Flint	0.3	2 +	97 +	4,385	1.4
Average .	1.3 +	9 +	89 +	....	....

of the three dusts used up to the present time in these tests — *i. e.*, crushed coal used for fuel in cement kilns, crushed raw cement rock and crushed flint used in pottery manufacture. These dusts were commercial products obtained from a cement plant in the Lehigh Valley and from a flint mill in Trenton, N. J., and, as will be seen in Table 2, averaged smaller particles than those entrained in the Palmer apparatus in tests made several years ago of air dustiness

in the mills from which these samples were obtained. Tables 2 and 3 give the percentage distribution as shown in Palmer samples of all particles small enough to enter the fine

TABLE 2.—SIZE DISTRIBUTION OF PARTICLES IN INDUSTRIAL DUST TESTS WITH PALMER APPARATUS

Kind of Dust	Av. Number of Particles per Cu. Ft. of Air	Number of Tests	Av. Weight of Dust per 100 Cu. Ft. of Air	Percentage of Particles	
				Under 5 Microns Size III	Over 5 Microns Sizes I and II
				%	%
Coal....	8,881,200	2	0.2286	53	47
Stone...	8,609,866	3	0.1681	55	45
Flint ...	844,040	3	0.0459	65	35

bronchioles and reach the lungs. Table 3 gives the results of counts of samples taken from the dusting box in which the animals were exposed and shows, by comparison with Table 1, that the Palmer apparatus, regardless of its total efficiency, seemed to take a fairly representative sample of the dangerous sized particles in these dusts.

Paraffin sections of portions of the lungs of guinea-pigs that had been exposed to the

TABLE 3.—SIZE DISTRIBUTION OF PARTICLES IN DUST TO WHICH GUINEA-PIGS WERE EXPOSED

(As Determined by Palmer Apparatus)

Kind of Dust	Av. Number of Particles per Cu. Ft. of Air	Number of Tests Sampled with Palmer Apparatus	Av. Weight of Dust per 100 Cu. Ft. of Air	Percentage of Particles	
				Under 5 Microns Size III	Over 5 Microns Sizes I and II
			gm.	%	%
Coal....	24,074,000	6	0.164	84.0	16.0
Stone...	4,719,000	12	0.046	93.25	6.75
Flint ...	15,009,000	6	0.0504	96.68	3.32

dusts for different periods and then killed by gas immediately after exposure, or at increasing intervals after, were stained and examined under the microscope. Simple alum-carmine staining permits the dust particles in the lungs to be seen clearly. The sections were examined under the oil immersion lens, and camera lucida drawings were made of a number of groups of intracellular particles. By this means a 2,000-diameter magnification was obtained and particles ½ micron in diameter and over could be measured. Table 4 gives the results of the measurement by these means of over 1,200 particles of the three dusts used; Table 5 gives the percentage distribution of particles grouped as over 5 microns (corresponding to sizes I and II) and under 5 microns (corresponding to size III). The

TABLE 4.—SIZE DISTRIBUTION OF DUST PARTICLES IN LUNG TISSUE OF GUINEA-PIGS

(Stained Sections)

Kind of Dust	Number of Particles Counted	Greatest Diameter of Particles in Microns								
		11	8	7	5	4	3	2	1	0.5
Coal.....	616	1	1	3	14	4	41	87	117	348
Stone.....	378	..	..	..	1	..	4	21	76	276
Flint.....	295	..	..	..	..	..	3	19	61	212
Total particles counted.....	1,289	1	1	3	15	4	48	127	254	836

latter are again divided into those under 1 micron and those from 1 to 4 microns. This division shows that apparently over 64 per cent. of the particles are under 1 micron, over 33 per cent. from 1 to 4 microns, with over 98 per cent. in the third class according to the Palmer count, while the dust itself showed an average of over 91 per cent. in the third class. Tables 4 and 5 show also an apparently decided difference in size distribution of particles of the lighter coal dust and the heavier stone and flint dust. Over 43 per cent. of the particles of coal dust found in the lungs were 1 micron or over in diameter, and particles as large as 11 microns were found, while less than 30 per

cent. of particles of either stone or flint were as large as 1 micron. The relative weights of the three dusts are shown in the last column of Table 1.

McCrae (8), in his studies on the lungs of South African hard rock miners, found

TABLE 5. — PERCENTAGE DISTRIBUTION OF DUST PARTICLES IN LUNG TISSUE OF GUINEA-PIGS

(Stained Sections)

Kind of Dust	Number of Particles Counted	Percentage of Particles in Size Groups			
		Over 5 Microns	1–4 Microns	Under 1 Micron	Total under 5 Microns
		%	%	%	%
Coal.....	616	3 +	40	56 +	96 +
Stone.....	378	0.2 +	26 +	73 +	99 +
Flint.....	295	0.0	28 +	71 +	100
Total particles counted	1,289	1.5 +	33 +	64 +	98 +

that by acid digestion of lung tissue he could recover silica particles, 70 per cent. of which were under 1 micron in diameter, with 30 per cent. ranging from 1 to 10 microns in diameter. These results compare very closely with the counts made by us, as will be seen by referring again to Table 5 in which flint and stone dusts averaged 27 + per cent. of particles above 1 micron and 72 + per cent. under 1 micron, as against the 30 and 70 per cent. respectively counted by McCrae in miners' lungs. Watkins-Pitchford and Moir (9) counted the doubly-refracting particles in sections of silicotic lungs ranging from 1 to 13 microns in diameter with a mean size of 6.13 by 2.18 microns, with particles up to 13 microns actually seen as intracellular. Later, by a method of cold digestion with strong nitric acid of the paraffin sections fixed on microscopic slides, they found that they had overlooked many particles and underestimated the size of others. After this treatment they counted and carefully measured 120 particles ranging from $\frac{1}{3}$ micron up to 5.5 microns in diameter, 35.8 per cent. being under 1 micron, 48 + per cent. from 1 to 2 microns, and over 15 per cent. above 2 microns in diameter, 1 micron being the most frequent size.

Sections from some of the same blocks of tissue from which stained sections were counted were treated by us according to the Watkins-Pitchford method of cold nitric acid digestion. Table 6 gives the results of these counts which compare closely with those of Watkins-Pitchford and Moir. We counted more large particles by this method than we did in stained sections, as did they. Although this method showed a surprisingly high percentage of large par-

TABLE 6. — SIZE DISTRIBUTION OF DUST PARTICLES IN LUNG TISSUE OF GUINEA-PIGS AS DETERMINED BY COLD ACID DIGESTION

(Watkins-Pitchford Method)

Kind of Dust	Total Particles Counted	Greatest Diameter of Particles in Microns [1]													Per Cent. over 12 Microns	Per Cent. over 5 Microns	Per Cent. 1–4 Microns	Per Cent. under 1 Micron
		23	17	12	9	8	7	6	5	4	3	2	1	0.5				
Coal.....	506	..	..	..	1	..	2	1	4	4	16	78	331	69	....	1.5 +	84 +	13 +
Stone.....	477	1	1	..	2	..	2	..	4	7	20	58	298	84	0.4 +	1.6 +	80 +	17 +
Flint.....	204	..	..	1	..	1	2	..	3	4	11	20	115	47	....	3 +	73 +	23 +
Total.....	1,187	1	1	1	3	1	6	1	11	15	47	156	744	200	0.1 +	1.9 +	81 +	16 +

[1] Most frequent size of all three dusts, 1 micron diameter.

ticles of stone and flint, yet the same relative distribution of smaller particles is seen. Coal dust showed only 13+per cent. of countable particles under 1 micron, and 65+per cent. averaging 1 micron in diameter; stone showed 17+per cent. under 1 micron, and 62 per cent. averaging 1 micron; and flint 23+per cent. under 1 micron, and 56+per cent. averaging 1 micron. With all three dusts the most frequent size found in the lungs was 1 micron (62+per cent. average), and there was an average of 81+per cent. from 1 to 4 microns. The same relatively high percentage of larger sized coal particles as compared with heavier stone and flint particles is seen here as is obtained by the direct counting of stained sections, though the difference is not so marked. Evidently, in the stained sections, many large particles of stone and flint appeared to be smaller than they really were, or probably were counted as more than one.

Table 7 is a comparison of percentage counts by all methods and shows a very close paralleling of size distribution of the countable particles under 40 microns in the original dust, the Palmer sampled dust, and the dust in the lungs of the exposed animals. While the tissue sections gave evidence by both counting methods of some clumping of very minute unmeasurable particles, yet these clumps were not very numerous and evidently were not the predominating factor, and hardly seem to be the factor apt to be responsible for much tissue damage. This would indicate that an average of 97+per cent. of the countable particles were among those counted as size III in the Palmer method according to Smyth's modification, as compared with 91 per cent. of the same size, counted in Palmer samples of the dust to which animals were exposed, and 89 per cent. in samples taken directly from the dust. The irregularity of the counts of particles over 5 microns in the different methods is explained by their relative infrequency in all tests.

These methods seem to indicate that a fair efficiency test of a dust sampling apparatus would include many particles of 1 micron in diameter and larger, and that failure to retain a high percentage of particles under 0.5 microns in diameter does not materially reduce its practical efficiency as a hygienic test. This is in practical agreement with and helps to confirm the opinion of the American Public Health Association Committee on Standard Methods for the Examination of the Air (10).

We are constantly exposed to and inhale

TABLE 7. — COMPARATIVE SIZE DISTRIBUTION OF DUST PARTICLES AS SHOWN BY COUNTS OF DUST, OF DUST CLOUDS, OF STAINED LUNG SECTIONS, AND OF ACID-DIGESTED LUNG SECTIONS[1]

Kind of dust	Av. 40 Microns				5–30 Microns				Av. 1 Micron			
	1	2	3	4	1	2	3	4	1	2	3	4
	%	%	%	%	%	%	%	%	%	%	%	%
Coal	2.9+	1.5	0	0	16+	14	3+	1.5+	81+	84+	96+	98+
Stone	0.78	1.5	0	0	9+	5+	0.2+	2+	90+	93+	99+	97+
Flint	0.3	0.07+	0	0	2+	3+	0.0	3+	97+	96+	100+	96+
Average	1.3+	1+	0	0	9+	7+	1+	2+	89+	91+	98+	97+

[1] 1 = Direct counts from dust.
2 = Palmer samples of dust.
3 = Stained lung sections.
4 = Acid-digested lung sections.

ultramicroscopic dust which is present in more or less degree in all air of inhabited regions. It is this type of particle that gives us our diffuse daylight and our beautiful sunsets, and that is responsible for much mist and cloud formation. These extremely minute particles remain in suspension indefinitely, as long as there are any air currents, being precipitated only in perfectly still air. In the bronchioles they would be the last particles to be deposited on the mucus, would float longest on the surface of the mucosa, would be the easiest to be swept up and out by the currents kept in motion by the cilia, and would be the least irritating when phagocytized. Ultramicroscopic particles are more apt to be spherical and less apt to be spiculate or to have sharp angles, and hard, spiculate or angular dusts are generally conceded to be most irritating and most apt to cause fibrosis. Especially with moderate degrees of dustiness, it would seem from the above considerations that the largest particles reaching the bronchioles would be the most irritating, and that of these larger particles the most dangerous would be the size occurring most frequently. This depends on the specific gravity and nature of the dust, and the efficiency of a dust sampling method should depend on its ability to retain a large percentage of these particles rather than of those of ultramicroscopic size.

As previously stated, both Bill's and Katz's tests with the Palmer apparatus were run at 4 cubic feet per minute, while we usually employ a 5 cubic foot rate with our type of apparatus. Katz states that he and his co-workers found a 30 per cent. efficiency by the Tyndall test when running at 4 cubic feet per minute, as against a 20 per cent. efficiency at 3 cubic feet — a ratio of 1.5 for the 4 cubic foot rate to 1 for the 3 cubic foot rate. Three comparative tests were run by us for five-minute periods against a very heavy cloud of coal dust which at the 5 cubic foot rate showed 1.3448 gm. of dust per 100 cubic feet of air. The tests were all run on the same day, the dust being freshly stirred up before each test so as to have as nearly as possible the same amount of dust in the air. There was absolutely no evidence of any water being carried through the apparatus, and with the very heavy content of coal dust in the water this could not have escaped observation. These tests show (see Table 8a) the same relative efficiency as that found by Katz for the 4 cubic foot rate as compared with the 3 cubic foot rate, and a ratio of 1.33+ for the 5 cubic foot rate as compared with the 4 cubic foot rate. This seems to indicate that if Bill had used the older type of apparatus at a 5 cubic

TABLE 8.—RELATIVE EFFICIENCY TESTS OF PALMER APPARATUS WHEN RUN TO SAMPLE 3, 4, AND 5 CUBIC FEET OF AIR PER MINUTE

a. By Weight

Dust Employed	Duration of Test	Rate of Air Flow per Minute	Total Air Sampled	Weight of Dust Washed from Air	Calculated Weight Dust per Cu. Ft. of Air
	min.	*cu. ft.*	*cu. ft.*	*gm.*	*gm.*
Coal.....	5	3	15	0.1004	0.66264
"	5	4	20	0.2012	1.006
"	5	5	25	0.3362	1.3448 [1]

b. By Count

Dust Employed	Rate of Air Flow per Minute	Per Cent. Size I, Av. 40 Microns	Per Cent. Size II, 5–30 Microns	Per Cent. Size III, Av. 1 Micron	Calculated Number of Particles per Cu. Ft. of Air
	cu. ft.				
Coal.....	3	6.4	34.4	59.2	37,333,300
"	4	1.1	27.0	71.9	66,800,000
"	5	0.52	8.6	90.8	66,800,000 [1]

[1] Both count and weight should have been higher for the 5 cubic foot rate sample but there was so much coal in the collecting bulb that over 100 c.c. of sample was obtained before the bulb was completely rinsed out. Some of the coal remained in the bulb and was not included in the count or in the weighing test.

foot rate he would have found it to have a relative efficiency of 81.8 per cent. by weight as compared with his apparatus; and with the same apparatus at the same rate, Katz would have found an absolute efficiency of approximately 59.85 per cent., instead of 45 per cent. at the 4 cubic foot rate.

Table 8b shows that the 5 cubic foot per minute rate also gives a greater efficiency by count than does the slower rate, and that the more active bubbling fountain entrains and holds back a great proportion of the smaller particles most apt to be harmful (size III).

Summary and Conclusions

Our findings as to size distribution of dust particles in guinea-pig lungs agree closely with those of McCrae and of Watkins-Pitchford and Moir in human lungs.

The most frequent sized dust particles lodging in the lungs of men or animals are those about 1 micron in diameter, and from 60 to 80 per cent. of the countable particles are from 1 to 5 microns in diameter. There is no evidence of a great accumulation of ultramicroscopic particles in the lung, and these particles are not so apt to reach the lung cells as are those which are somewhat larger.

Dust particles seen in stained sections of the lungs are apt to appear smaller than they really are, as is shown by the Watkins-Pitchford method of cold acid digestion.

The Tyndall phenomenon, depending largely on the presence of ultramicroscopic particles in the air, although the best absolute test of complete removal of particulate matter, is too severe a test of the practical hygienic efficiency of a dust sampling apparatus. Efficiency tests for such apparatus should be made with dusts containing particles at least as large as 10 microns in diameter, and the most frequent size in such test dusts should be 1 micron in diameter.

With dusts having particles ranging up to 40 microns in diameter, and with an average of over 89 per cent. of particles under 5 microns in diameter, the Palmer apparatus run at 5 cubic feet per minute collects representative samples with nearly the same size distributions. A five cubic foot per minute rate is the most efficient for the Palmer apparatus as originally designed, and does not carry any water through the apparatus. At this rate, it is at least 1.33 times as efficient as is the new design run at the 4 cubic foot per minute rate, as was done by Bill and Katz. At the 5 cubic foot per minute rate the Palmer apparatus should have an efficiency of almost 82 per cent. by weight as compared with the Bill electrostatic apparatus. At this rate the increase in numerical efficiency and the percentage of smallest sized particles are both decidedly greater than at the 4 cubic foot per minute rate.

The electrostatic method of dust sampling as used by Bill would undoubtedly be the best method, provided a simple, easily manipulated, portable apparatus were devised.

The clumping of minute particles in Palmer dust samples as objected to by Bill can usually be overcome by sufficient dilution and shaking, which will greatly increase the numerical efficiency of the method. At present the Palmer apparatus is the most efficient practical dust sampling apparatus at our disposal for hygienic tests in industry.

The Kotzé konimeter (10) was not considered in the above comparisons because, regardless of its absolute efficiency or its efficiency for sampling dangerous sized particles, it collects too small a sample over too short a period to give an idea of the amount of dust to which a laborer is exposed in his daily work.

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PHYSICAL EDUCATION FROM THE STANDPOINT OF THE INDUSTRIAL PHYSICIAN*

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ONE of the chief functions of an industrial medical clinic is that of a "diagnostic clearing house." Yet, too often, this real opportunity for service is lost sight of in the routine treatment of trivial cases and the dressing of minor injuries. Even physical examinations are made in a methodical manner and the cards filed without any attempt being made to cull out the cases which could be benefited by simple hygienic measures. An applicant is rejected or employed with little or no thought beyond the fact that he is either fit or unfit. Too often he is not even told why he is rejected, and as a result he drifts from one industry to another until he finally gets a job in a factory that does not require the physical examination of applicants.

In many of our better organized industries, physical examinations are required of all applicants for employment. Re-examinations are made at periodic intervals, at least once a year, and more frequently if it seems advisable to the examining physician or to the foremen or superintendents of departments. Re-examination is beneficial to the employer because it gives him efficient workers; to the employee because it serves to keep him in good physical condition; and to the examining physician because it gives him valuable information as to conditions under which certain defectives do well. Very often applicants and old employees who are manifestly physically below par present themselves for examination, and yet it would be a simple matter to raise them to an average standing of physical fitness if a physical education department, thoroughly organized under efficient leadership, were available, as it were, to fill the prescription of the examining physician. I believe that one of the most important functions of the present day industrial physical training department is to carry out, under the direction of the medical department, such measures as may help to restore the applicant or the employee to normal health. Then, too, there are the abnormal cases which require special care — persons with defective hearts, those with arteriosclerosis and high blood pressure, those who are greatly overweight or underweight, or those who are poorly nourished and whose resistance is manifestly low. We industrial physicians are comparatively helpless without someone to assist us in the upbuilding of these bodies which need individual care rather than routine work in gymnasium classes. It would be foolish to prescribe the same drug in all cases of illness with the thought that it would be a cure-all. Is it not equally absurd to expect the same form of exercise to benefit individuals irrespective of their physical defects? The physician and the physical director should hold a consultation over each individual case in order that the physical director may be fully informed in regard to the condition which he is to try to remedy. Otherwise, a heart only slightly involved may be permanently damaged, or an overtaxed circulation broken down by misdirected efforts.

In several industrial institutions groups of employees are assembled on a gymnasium floor or an adjacent field and put through a series of exercises. Calisthenics are a bore to the majority of people, and

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apparatus work is too difficult or monotonous for the average person to approach with any degree of enthusiasm. Glowing reports of the success of these group classes are received but individually the employees say: "We have to do it because the boss does. We would rather be playing ball." Play! That is the answer — the spirit of competition, the elemental desire in each heart to excel the other fellow.

The tendency in some industrial physical training departments is to develop teams very closely verging on professionalism. In many of our industrial leagues the sole object seems to be to organize such teams for advertising purposes. In fact, many ex-professional athletes are given a nominal place on the payroll merely so that they may participate in athletics. This is closely analogous to the old custom of hiring professional athletes to attend college and giving them their tuition and board in return for their participation in certain forms of athletics. In a recent conference a group of men engaged in industrial physical training deplored this tendency and agreed with the physicians present that this should not be the sole object of physical training in industry. On the other hand, there is the human factor that must be considered — that is, the reluctance which most of us have to engage publicly in a sport in which we realize that we are not very proficient. We would rather sit on the side lines and watch others play ball or tennis, or engage in field events, than to go in and try them ourselves and be laughed at because we are "dubs."

There, I think, is the important problem to be solved. How are we to get the bench warmers out on the field? Certainly not by encouraging the development of so-called professional industrial teams, but rather, it seems to me, by the development of playground activities. In one factory which I recently visited the building was locked during the noon hour and all the employees went out of doors as soon as they had finished lunch. I saw more people playing volley ball at one time in that yard than I have ever, before or since, seen playing the game. Besides volley ball there were several games of indoor baseball and two games of ordinary baseball going on, while over in one corner of the yard a number of fellows were pitching horseshoes. Nearly everybody was doing something and but few were looking on. Some, it is true, had left the grounds and gone for a walk, but no one returned to the factory directly after luncheon.

A point that should be emphasized as essential to the success of outdoor recreation is that the playground should be close to the factory, preferably on the same lot, in order that it may be reached with no loss of time and in order that there may be a feeling of greater freedom among the employees because they are, so to speak, playing in their own back yard. If this scheme of playground activities could be still further perfected by being organized under the direction of a playground leader, much more might be accomplished than under the present system.

There is one beneficial result of playground activities that is permanent; when the weather becomes inclement these young people, who have become accustomed to play for a half or three-quarters of an hour during each noon recess, will miss their play time and will naturally drift into the gymnasium during the winter months. The gymnasium, therefore, is in this way secondary to the playground, and with bowling, basket ball and other indoor sports will continue the beneficial habits formed by play in the open. One serious drawback to gymnasium work, however, is that so few can enjoy it at one time, and therefore our problem is again to make the spectator play. This may be accomplished by providing as means of recreation

other amusements which require little or no equipment, such as dancing, for which only a phonograph is necessary; indoor quoits; checkers; and singing, which is extremely good breathing exercise. Not long ago I heard two or three hundred young people sing in a factory dining-room after lunch. One of the foremen acted as leader and one of the girls accompanied them on the piano. And how they did enjoy it! Yes, I sang too, as did everyone else.

Practically all outdoor sports and recreational activities that have been participated in by women and girls are but adaptations of sports and games indulged in by men and boys. Baseball, for example, is not a natural game for a girl to play and very few girls make good ball players. The same may possibly be said of basket ball. It seems, therefore, that there is a large field still open for the development of games especially applicable to the needs of women.

It is not the purpose of this paper to go into the great subject of fatigue, nor to point out the methods of measuring fatigue, but we must acknowledge that it constitutes the most difficult problem to solve in all industrial relations. Fatigue is the most common cause of breakage, of wastage, of poor quality of product, of accidents, and of lessened production. Some writers say that there is no such thing as fatigue, that it all resolves itself into an antipathy aroused by monotonous occupation. Manifestly this is not so. However we may approach this subject, however skeptical we may be from a medical standpoint, we do see evidences of fatigue among workers. This is especially true among those engaged in piecework in shops where there is a long working day. If you doubt this, try it yourself. Pick out some simple manufacturing process that is easy to learn and then sit down and do that bit of work for four successive hours. Then eat a light lunch and go back to work after half an hour for another four or five hours. As a result you will be very tired, nervous or unstrung and, undoubtedly, irritable. It has been said that, if fatigue causes a net loss of five cents a day to each worker in the United States, in a year it will amount to the stupendous sum of $300,000,000. There must be some remedy for fatigue, but it is not a universal remedy and therefore cannot be applied as a general rule, but must be adapted to each process of manufacture after an exhaustive study of that particular industry.

Many processes in industry are in themselves fatiguing either because of the monotony of the operation or because of the physical effort required to do them well. Among the workers engaged in such processes there are always some who for no apparent reason lag behind in production, especially if they are doing piecework. Sometimes this is so apparent that it is manifestly due to some inherent defect in the technic, too long hours or poor hygienic surroundings. Personally, however, I believe that it is monotony which has this effect, and that in order to overcome this and thereby decrease spoilage and accidents and increase production it is necessary to have recess periods during the working hours. No definite rule, however, can be laid down for these recesses. In office work it is a simple matter. All that is necessary is an opportunity to move about and if possible, under suitable direction, to take some simple relaxing or corrective exercises with the windows open. I have seen this experiment tried out in one office, and the manager says that exercises are now an accepted part of the day's work. Certain trade unions have specified in their agreements with their employers that a definite amount of time be given each day during the working hours for relaxation. They have found this necessary because of the nature of the

process of manufacture. On the other hand, there are a vast majority of workers who need these recess periods but who do not realize their need, and whose employers are also oblivious to this cause of fatigue. Physical relaxation and exercise during working hours are of great importance and should be given careful consideration by each plant manager after he has made a careful survey of physical conditions of the operators and processes, with the aid of his medical staff. Conditions vary, and remedies must, therefore, be chosen to meet existing conditions.

In the large cities where many workers must spend from one hour to three hours each day going to and from the factory, the question of games and sports outside of working hours must often be limited by the time available. It is practically impossible to induce anybody to remain for an hour or so after work to take up any form of recreational activity. A few may stay and play baseball or bowl, but the majority choose to go home. They are tired and hungry, and they want to get out of their working clothes. It is apparent, therefore, that if exercise out of working hours is to be indulged in by the majority of workers, it must be arranged for in the middle of the day. If the working day is eight hours long, there should be at least one hour at noon for a light luncheon and recreation. Again games are the best means of relaxation, but these games should be simple; first, in order that all may play and, secondly, in order that they may be completed in the brief time allotted. Naturally, the physical instructor should here become the playground director, and it is his duty to arouse the interest of the bench warmers and keep things moving.

In all of our industries one encounters the sad spectacle of twisted hands and fingers, ugly deformities and scars with resulting contractions. I believe these are a blot on a community, a disgrace to industry and a shame to the medical profession. They should be eliminated, and they can be by co-operation between the physical education department and the medical department. But you say that methods for the relief of these deformities are expensive, that the cost is prohibitive for any one factory. True, but why should not combined industry contribute toward local hospitals and see that a ward or building is suitably equipped and maintained for the care of this class of patients? Imagine the tremendous saving not only of dollars, but of thousands of dollars, annually if the stiffened fingers and hands could be treated and kept limber and functioning. After it is too late, after adhesions have formed and the need is only too apparent, a belated attempt is made to correct the impossible. Treatment should follow immediately upon the surgical procedure; the injured fingers should never be allowed to become stiffened and contraction should never be allowed to occur. But it is only by individual care and by constant supervision and manipulation of these crippled members everyday, sometimes every two or three hours, that successful results can be obtained. In a certain city of a million inhabitants, with 3,000 industries, there is not even one well-equipped hospital or dispensary to handle the vast multitude of such cases that present themselves each year.

Perhaps it is not the function of a paper of this character to mention the beneficial effects of preventative measures applicable to club feet, flat feet, and other acquired or congenital deformities that are occasionally seen in industrial clinics, and yet we know that many of these conditions even could be helped or prevented by simple measures similar to those which have been mentioned above for the treatment of occupational deformities.

The chief criticism that has been made of this rather extensive program for phys-

ical education is that it would be expensive to put into operation. It would require the services of a man well trained in gymnasium and playground activities, and would necessitate the installation of more or less expensive equipment. There is no reason why a beginning, however small, could not be made in almost all industries. The first requisite is a vacant lot. The tendency is for young people to play wherever there is a vacant piece of property. They may be interested in baseball or some other outdoor sport, but in any event, they tend to gather together and to play something. If somebody can be secured to direct them, even though it be a volunteer from among their own numbers, it will be a beginning which is sure to bear fruit in the long run. I do not believe it is the province of industrial organizations to try to reach the high standard of equipment which has been installed in some places and which is so elaborate that the expense is prohibitive to most companies. But at any rate let us make a beginning. The workers themselves will take care of the rest as the spirit of play becomes a part of the routine of their day's work.

The industrial executive has three problems always before him — production, quality, and people. He feels that it is the function of the medical department to provide him with workers physically able to give him the maximum production, and realizes that the quality of output, too, is inseparable from good health and good spirits. The medical department and the physical education department cannot fail to succeed if they will work together and strive to co-operate with executives on the one hand, and the workers on the other.